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Final Report for Fall 2005 & Spring 2006, Legacy Program: Migratory Bird Monitoring Using Automated Acoustic and Internet Technologies

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Final Report for Fall 2005 and Spring 2006, Legacy Program: ***Migratory Bird Monitoring Using Automated Acoustic and Internet Technologies***

Summary

Cornell Laboratory of Ornithology (CLO) developed digital autonomous recording units (ARUs) that record mp3 and binary (BIN) sound files for periods of up to 6 weeks in duration. We address the limiting factors of observers monitoring birds acoustically and of protocols monitoring birds that may be missed by traditional observation methods and provide solutions and sample data that enhance DoD's capacity to monitor avian resources on and around DoD lands and analysis and summary of these data. We also examine ARU reliability, applicability to tasks, and recording quality. We tested all devices with the planned application of this technology: to monitor acoustically species that vocalize infrequently, to improving accuracy of existing census methods, to produce acoustic datasets for training purposes, and to monitor flight-calls of migrant birds for predicting migration and stopover use on DoD installations. We collected over 27,000 hours of data in fall 2005 and spring 2006, and we have successfully stored, processed, and initiated analysis of this information. We outline problems and constraints we encountered in developing and applying hardware and software technologies. We indicate future areas to improve our data collection and analysis, to expand our research, and to form partnership that will further bolster the use of this technology.

Brief Background

Acoustical methods play a prominent role in avian monitoring efforts because many birds can be heard more reliably and at much greater ranges than they can be seen (for example, all bird detections at 37% of study sites in Hawaiian study were aural; Scott et al. 1981). However, three factors constrain the robust translation of bird sound detections into reliable estimates of density: 1) human listeners differ significantly in hearing thresholds and psychoacoustic acuity (Cyr 1981, Ramsey and Scott 1981); 2) human observers vary in their ability to identify sounds, cope with dense choruses and judge distances to bird sounds (Faanes and Bystrak 1981, Emlen and DeJong 1981); and 3) the patterns of bird sound production (rates) are inadequately quantified (Diehl 1981, Ekman 1981, Best 1981). These limitations apply to ground-based monitoring of diurnal, terrestrial birds and to monitoring of the vast numbers of aerial, nocturnal migrants that vocalize in flight.

Objectives for Year One

Cornell Laboratory of Ornithology (CLO) developed digital autonomous recording units (ARUs) that record acoustic data for periods of up to several months in duration. These units can provide a valuable extension to traditional point counts because they can detect species that are not censused efficiently by point count methods because they vocalize infrequently, and be deployed in advance at many sites and programmed to record simultaneously to produce true matched samples enabling ground personnel to cover more sites. These devices are also useful for monitoring audible bird migration. We proposed to accomplish the following tasks:

> 1) to test and evaluate protocols for using digital autonomous recording units (ARUs) to a) enable ground-based acoustic censusing of species that vocalize infrequently, b) provide critical data to improve the accuracy of any acoustic census, and c) produce acoustic datasets for observer training;

2) to implement and ground-truth a network of acoustic detectors to monitor flight-calls (FCs) of migrating species, to predict species-specific stopover use on and around DoD installations; and

3) to customize the Internet-based eBird application to allow DoD to collect, store, and manage sighting data on all bird species throughout the year.

The first two components address directly the limiting factors of observers monitoring birds acoustically and monitoring birds that may otherwise be missed by traditional observation methods and provide solutions that will enhance DoD's capacity to monitor avian resources on and around DoD lands. The third component facilitates the analysis and summary of these data as well as their presentation in a convenient and accessible format.

Methodology

Many migratory bird species produce FCs audible from the ground (Ball 1952, Graber and Cochran 1959, Evans and O'Brien 2002, Farnsworth 2005), and many of these vocalizations are stereotyped and species-specific (Evans 1994, Evans and Mellinger 1999, Evans and Rosenberg 2000, Evans and O'Brien 2002). Automated detection and identification of FCs affords an opportunity to monitor nightly bird migration over and around DoD installations. These FCs are short and simple vocalizations, and automatic identification has been demonstrated for some guilds. For example, during a 1999 EPA-funded project called BirdCast (Mills 2000, Hedges 2001), CLO produced preamplified microphones and a Java application that enabled volunteers to automatically detect FCs using the sound card inputs on their personal computers. FCs were uploaded over the Internet each morning, and logged in a database that hosted graphical tools for reviewing and labeling the sounds. Numbers of migrants detected at night were then compared directly with ground-based censuses from nearby sites, to assess the composition of species passing overhead versus stopping to use habitats on the ground. These numbers also were compared with NEXRAD radar imagery, providing information on the species composition of radar-detected migration events (additional similar studies: Larkin et al. 2002, Farnsworth et al. 2004). We followed a similar approach to the collection of acoustic data for the first year of this project.

In Fall 2005 and Spring 2006 CLO staff undertook two studies to advance migratory bird monitoring: installation of a wide aperture nocturnal flight-call network, and assessments of point count performance utilizing a lightweight stereo recording system. CLO and DoD personnel installed acoustic monitoring arrays at seven sites stretching from the border with Canada to the southern end of the Chesapeake Bay, six bases and one non-DoD site at Mount Pleasant in the Finger Lakes region of central New York (approximately 4 miles from CLO) to fill a gap in geographic coverage and to provide a convenient array for testing (Figure 1). The fall deployment fulfilled several practical needs: obtaining the necessary permissions, finding suitable locations for monitoring equipment, developing efficient deployment protocols, and extended field testing of new Autonomous Recording Units (ARU). The spring deployment afforded us an opportunity to correct some of the problems we experienced during the fall while collecting additional training datasets for use in developing energy detectors and flight-call temporal patterns.

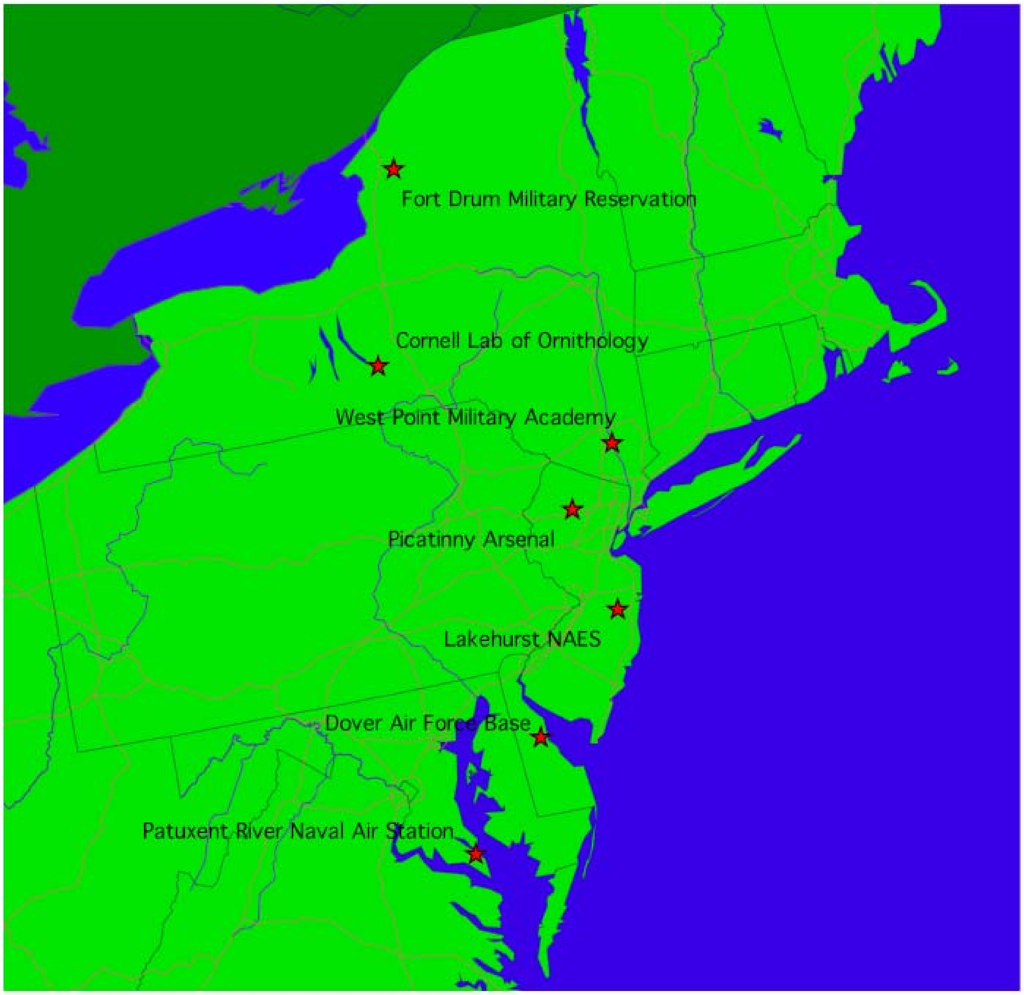

Figure 1: Locations of Autonomous Recording Unit (ARU) arrays for monitoring nocturnal flight-calls and documenting use of airspace above DoD installations by migrating songbirds. ARU arrays will also aid in documenting use of habitat within the installations for migratory stopovers.

We deployed ARUs as three-unit arrays designed to examine the feasibility of localizing flying birds. We positioned the three units in a triangular configuration at each site. This was done, in part, to provide redundancy for recording flight-calls of migrating songbirds, although we were not aware of any unit failures or the propensity for unit failure at the time and, in part, to enable us to estimate altitude of night flight-calls (FC) and bearings to them, to better document morning flight, and use of DoD lands for stopovers during migration. Each array consisted of three ARU placed approximately 50 m from each other. Each ARU consisted of a stereo pair of sensitive, horn-loaded, pre-amplified dynamic microphones feeding a recording unit that stored the sounds digitally on a 100 GB hard drive as compressed MP3 sound files. In spring 2006 we also deployed ARUs that record binary files (BIN), uncompressed sound files. Each ARU recorded 24 hours/day, 7 days/wk for approximately 70 days, generating approximately 100 GB of compressed sound data when units functioned at full capacity without failure. Each

BIN unit recorded during a pre-programmed schedule from civil twilight to civil twilight. The installations occurred in the following order: Mt. Pleasant, Ithaca, NY, Picatinny Arsenal, Mt. Hope, NJ, Naval Air Engineering Station, Lakehurst, NJ, Naval Air Station at Patuxent River, MD, West Point Military Academy, West Point, NY, Dover Air Force Base, Dover, DE, and Fort Drum Military Reservation, Fort Drum, NY. During fall we deployed and removed the units from north to south (except for Mt. Pleasant and Ft. Drum) in order to capture the maximal amount of FC and morning flight data, because high migration traffic persisted longer at southern sites. During spring we reversed the deployment strategy.

Acoustic monitoring and bird surveys

Pivotal questions regarding variability in observer performance and the utility of long-term recording equipment for bird monitoring motivated a second phase of Legacy data collection. The same horn-loaded microphones used in the ARUs were paired with compact, solid-state MP3 recorders (iRiver iFP-899, 1 GB flash memory, $300 total system cost) and sent out with bird monitoring personnel who conducted point count surveys. Three systems were sent out with the NY Audubon grassland survey team, who conducted hundreds of point counts throughout the state. In addition, a BBS survey route (50 stops) and an Ontario Bird Atlas block point count survey (30 stops) were recorded using the same equipment. The Canadian effort included real-time notes by an experienced observer as well as recordings made by two digital acoustic systems. The compact CLO unit was run in parallel with a more expensive and cumbersome system that was developed for Canadian forest surveys (E3A: $6900, http://www.riverforks.com/). These data will enable direct comparisons of performance between recording systems, as well as comparisons between the real-time and offline bird counts. This work in Canada enabled us to take advantage of later breeding activity at high latitudes, and we fostered a partnership with Dr. Charles Francis, the Chief of the Migratory Bird Population Division of the Canadian Wildlife Service. The success of acoustical technology development will rely on both the gains in monitoring performance that can be realized and broad acceptance by the ornithological community.

Preliminary Results

We summarized total data generated by the 21 ARU deployed in seven arrays by location in Table 1 (a and b). We recorded a total of over 27,000 hours during deployments in 2005 and 2006 (Table 2). We are currently analyzing the species composition of these recordings, and initial analyses have highlighted a number of challenges with these analyses that we discuss in the following sections. Additionally, we are using this substantial data set to exercise the automated processing software system and to develop statistical protocols for further data reduction and graphical display.

Year	Season	Location	Mount Pleasant	Lakehurst	Pax River	Picatinny	USMA	Dover AFB	Ft. Drum	Braddock Bay	Totals
		Code	MP	Lakeh	Pax	Pic	WP	Dover	FtDrum	BB	
2005	Fall	BIN (GB)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Recording Length (HH:MM:SS)	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00
		MP3 (GB)	176.1	102.0	141.0	206.3	94.9	115.0	118.0	0.0	953.3
		Recording Length (HH:MM:SS)	3282:44:55	1901:25:18	2628:26:09	3845:43:07	1769:37:37	2142:49:40	2199:41:02	0:00:00	17770:27:48
2006	Spring	BIN (GB)	33.1	76.7	56.6	0.0	0.0	0.0	0.0	75.1	241.5
		Recording Length (HH:MM:SS)	247:28:40	573:27:37	423:25:34	0:00:00	0:00:00	0:00:00	0:00:00	561:29:52	1805:51:42
		MP3 (GB)	0.0	99.0	0.0	125.7	130.0	0.0	51.0	0.0	405.7
		Recording Length (HH:MM:SS)	0:00:00	1845:29:51	0:00:00	2343:13:21	2423:22:50	0:00:00	950:52:53	0:00:00	7562:58:55
Totals by Location	GB	BIN	33.1	76.7	56.6	0.0	0.0	0.0	0.0	75.1	241.5
		MP3	176.1	201.0	141.0	332.0	224.9	115.0	169.0	0.0	1359.0
	Hours	BIN	247:28:40	573:27:37	423:25:34	0:00:00	0:00:00	0:00:00	0:00:00	561:29:52	1805:51:42
		MP3	3282:44:55	3746:55:09	2628:26:09	6188:56:28	4193:00:27	2142:49:40	3150:33:55	0:00:00	25333:26:43

Table 1a. Total data recorded by season and location in hours and gigabytes. Zeros (0)

represent sites without the recording unit type at the location.

Fall 2005			Spring 2006				
Deployment ID	No. files Recorded - MP3	Total size (GB) MP3	Deployment ID	No. files Recorded - MP3	Total size (GB) MP3	No. files recorded - BIN	Total Size (GB) BIN
Dover ARU n	27	22.0	BB ARU 1	NA	NA	29	30.0
Dover ARU se	94	92.4	BB ARU 2	NA	NA	19	18.2
Dover ARU sw	2	0.6	BB ARU 3	NA	NA	27	26.9
FtDrum ARU n	49	48.0	FtDrum ARU NW	1	0.0	NA	NA
FtDrum ARU ssw	26	25.0	FtDrum ARU W	53	51.0	NA	NA
FtDrum ARU w	47	45.0	Lakeh ARU 521	78	78.0	NA	NA
Lakeh ARU n	58	58.0	Lakeh ARU airalk	22	21.0	NA	NA
Lakeh ARU se	10	10.0	Lakeh ARU 1	NA	NA	14	12.8
Lakeh ARU sw	34	34.0	Lakeh ARU 2	NA	NA	27	27.8
MP ARU ne	33	32.1	Lakeh ARU 3	NA	NA	35	36.1
MP ARU nw	92	92.0	MP ARU 1	NA	NA	0	0.0
MP ARU s	52	52.0	MP ARU 2	NA	NA	21	21.4
Pax ARU ne	57	56.5	MP ARU 3	NA	NA	13	11.7
Pax ARU nw	57	56.5	Pax ARU 1	NA	NA	28	27.9
Pax ARU s	28	28.0	Pax ARU 2	NA	NA	2	0.8
Pic ARU nw	90	89.3	Pax ARU 3	NA	NA	28	27.9
Pic ARU nw	66	65.0	Pic ARU Far	89	87.7	NA	NA
Pic ARU s	52	52.0	Pic ARU Near	39	38.0	NA	NA
WP ARU n	38	36.9	USMA ARU 1	58	51.0	NA	NA
WP ARU se	50	48.7	USMA ARU 2	80	79.0	NA	NA
WP ARU sw	11	9.3					
TOTALS	**973**	**953.28**	**TOTALS**	**420.0**	**405.7**	**243.0**	**241.5**

Table 1b. Total number of files recorded and their sizes by season and station. NA represents locations at which we did not deploy the type of unit represented. Zeros (0) represent no data collected in the sound file, indicating a problematic recording unit. Codes follow Table 1a, with locations at recordings sites with multiple units indicated by typical cardinal directions.

Seasonal Totals					
Year	Format	Recording Length (HH:MM:SS)	GB	No. Locations	No. Units
2005	MP3	17770:27:48	953.3	7	21
	BIN	0:00:00	0.0	0	0
2006	MP3	7562:58:55	405.7	4	8
	BIN	1805:51:42	241.5	4	12
2005	Total	17770:27:48	953.3	7	21
2006	Total	9368:50:38	647.2	7	20
Combined	Total	27139:18:25	1600.5	7	41

Table 2. Seasonal totals of mp3 and BIN file recordings. Note that in 2005 we did not deploy any BIN units.

Sample flight-call temporal patterns and species composition

In an effort to examine what types of products we will produce once automated software is fully developed, we quantified the temporal pattern of the number of calls per hour on 8 October 2005 as recorded by an ARU at Dover AFB in Delaware (Figure 2a) and summarized the species composition (Figure 3). We also quantified the pattern of calls per hour without Savannah Sparrow, a species that winters regularly in the area of the sample dataset and likely on DoD land, thus correcting for the presence of possible bias generated by a non-migrating, wintering species (Figures 2b, 3). This temporal pattern is typical of both anecdotal reports of temporal patterns as well as published accounts (Ball 1952, Graber and Cochran 1960, Evans and Mellinger 1999, Evans and Rosenberg 2000, Farnsworth et al. 2004).

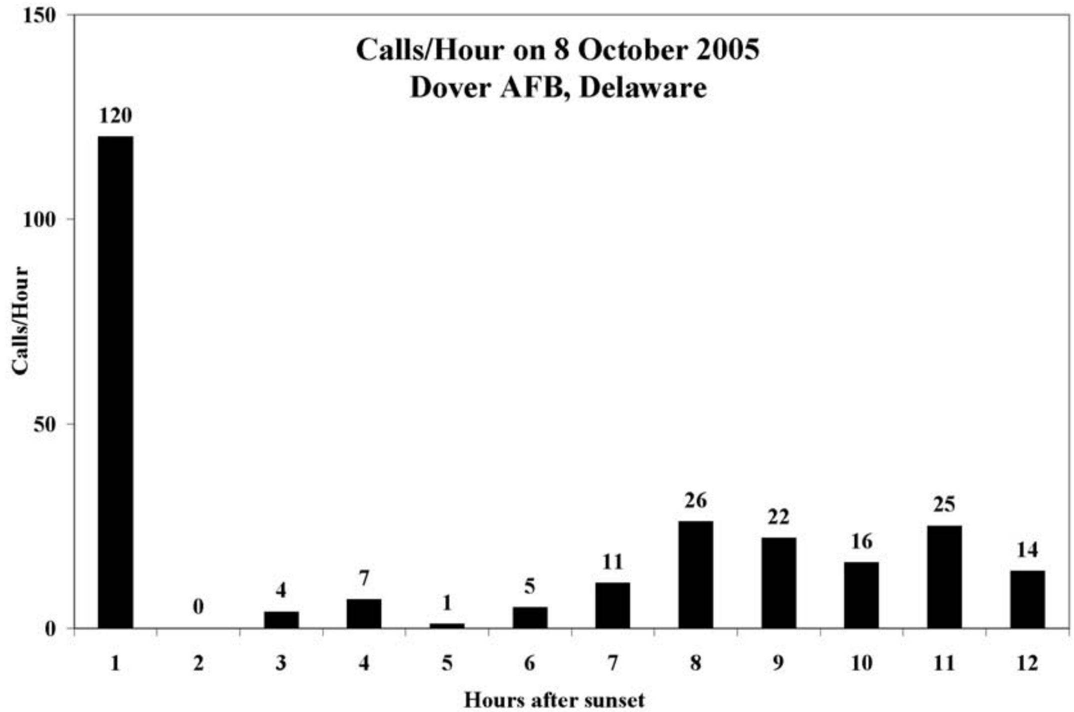

Figure 2a. Calls per hour at Dover AFB, Delaware on the night of 8 October 2005. Note the high call count for the first hour after sunset. This represents Savannah Sparrows, and these flight-calls may represent non-migrant individuals, and as such these calls bias the temporal pattern in a substantial way.

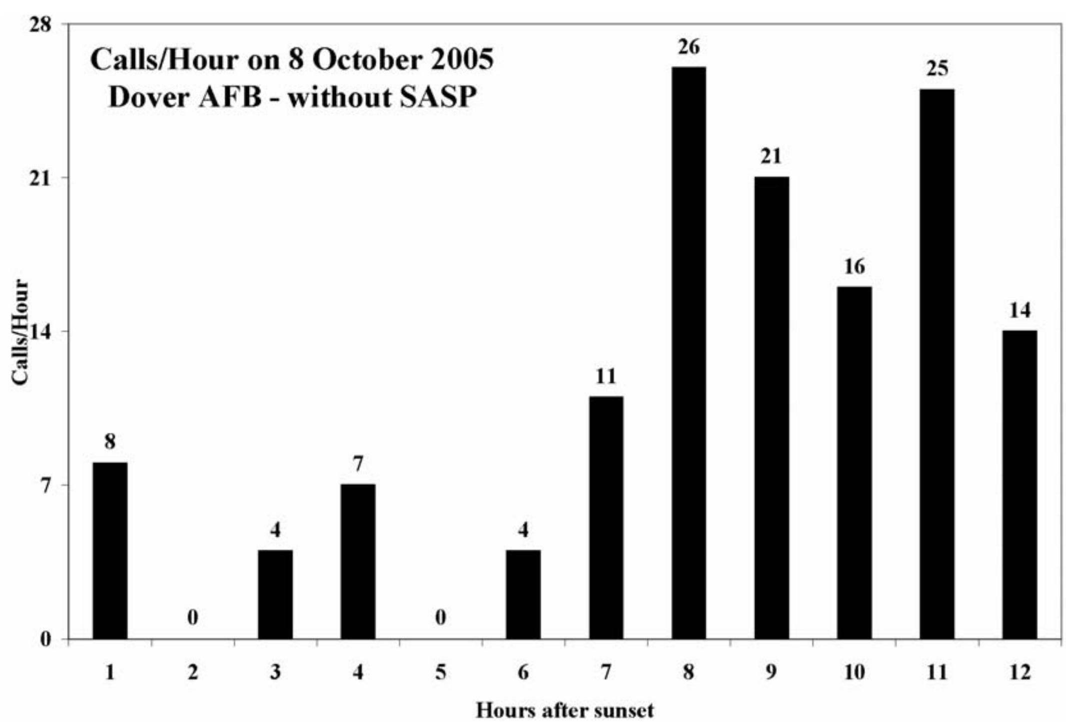

Figure 2b. Calls per hour at Dover AFB, Delaware on the night of 8 October 2005, without Savannah Sparrow flight-calls (SASP). Note the pattern of higher call counts closer to dawn, also observed in anecdotal accounts of flight-call temporal patterns and published accounts.

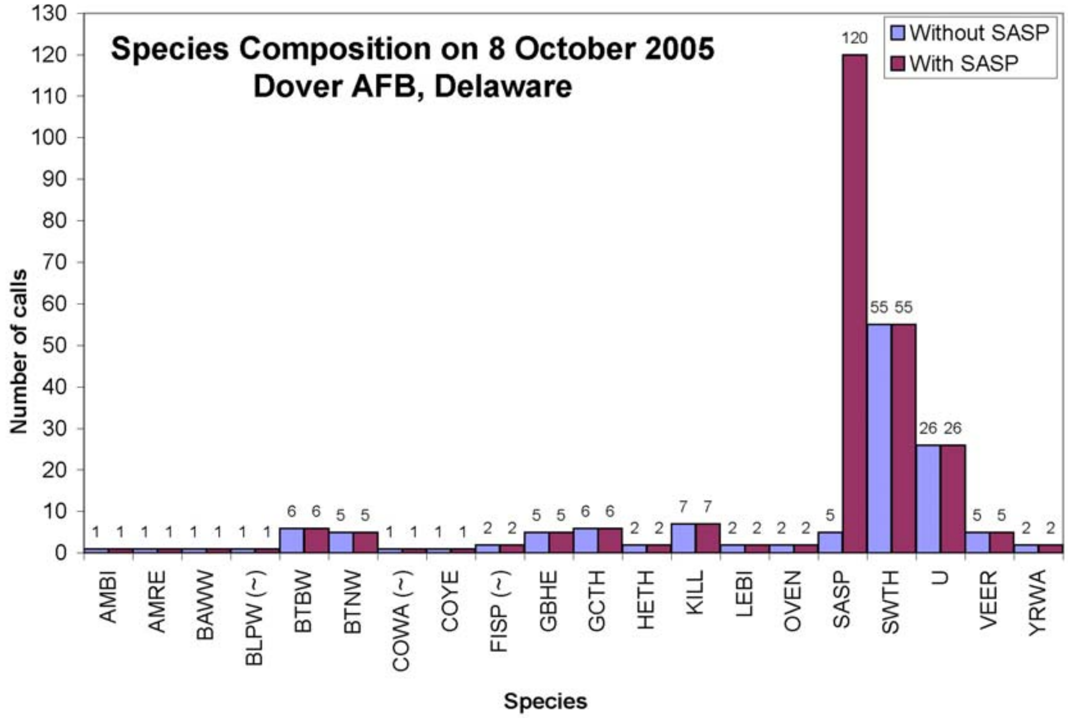

Figure 3. Species composition at Dover AFB, Delaware on the night of 8 October 2005. Note that Savannah Sparrow (SASP) composes a large portion of the total calls. These calls may represent non-migrant birds, hence the representation of "Without SASP" for comparison to represent a potentially less biased examination of the species composition of vocal migrants on this evening. Species abbreviation are: AMBI American Bittern, AMRE American Redstart, BAWW Black-and-white Warbler, BLPW Blackpoll Warbler, BTBW Black-throated Blue Warbler, BTNW Black-throated Green Warbler, COWA Connecticut Warbler, FISP Field Sparrow, GBHE Great Blue Heron, GCTH Gray-cheeked Thrush, HETH Hermit Thrush, KILL Killdeer, LEBI Least Bittern, OVEN Ovenbird, SASP Savannah Sparrow, SWTH Swainson's Thrush, U Unidentifiable, VEER Veery, YRWA Yellow-rumped Warbler. ~ indicates probable identifications due to poor spectrographic resolution of the flight-calls.

Future plans and considerations for deployments

Improved speed and consistency in analyzing data using sound analysis software

Our initial attempts to analyze recordings used two software packages, Raven 1.2 and XBAT 0.7. Neither program supported mp3 file analysis during the bulk of the first year of our data collection, so analyzing data in spectrographic form was impossible; because of the quantities of data we collected, real-time aural analysis of all the data was also impossible. In our first attempts at data processing and analysis, we needed to split all the mp3 files into segments, determine which of these segments corresponded to nocturnal and diurnal recordings, and then

convert these files to .aif sound files that could be opened in Raven and XBAT. In addition, without energy detection browsing these files for flight-calls required longer than real-time analysis, meaning that for each hour of recordings, some times 2-3 hours was needed to analyze flight-call data. This number is faster than real time for a trained flight-call analyst, perhaps approaching 3-5 times faster than real time. However, such tasks are clearly at the expense of analyzing flight-calls themselves and classifying them to species. Even a trained flight-call analyst could not sustain thousands of hours of analysis to detect flight-calls. However, these software platforms improved during 2006 and eventually facilitated direct (visual inspection and algorithm based “inspection” such as energy detection), faster-than-real-time analysis of mp3 files by late 2006. We overcame a number of problems associated with reading mp3 data, and are now able to load, visualize, play, and analyze these files. In addition, whereas it was not possible to open a single file in previous versions, we could view and analyze an entire deployment's files in a single session of XBAT by late 2006.

Toward the end of the first year, we began to make drastic improvements toward the proposed goal of automatic detection technology. We employed an energy detector that uses a series of adjustable parameters to locate signals of interest in a sound file and log those by time and frequency (Figure 4a, b, c). This procedure iteratively succeeded and failed, confirmed primarily by comparing logs of flight-calls flagged by an expert visually inspecting the sound file spectrograms with the logs generated automatically by the energy detection algorithms. However, this exercise greatly improved our abilities to detect flight-calls using parameter-based automatic detection algorithms, producing successful classifications at first in the 0-20% match range then successively up to 45-60% success. With continuing iterative research, we believe we will attain success as high as 80-90% detection of all calls in audio files classified visually and aurally by human flight-call experts. This will substantially reduce the time required to analyze flight-call data because automatic detectors are now working at speeds 10-20 times faster than real time.

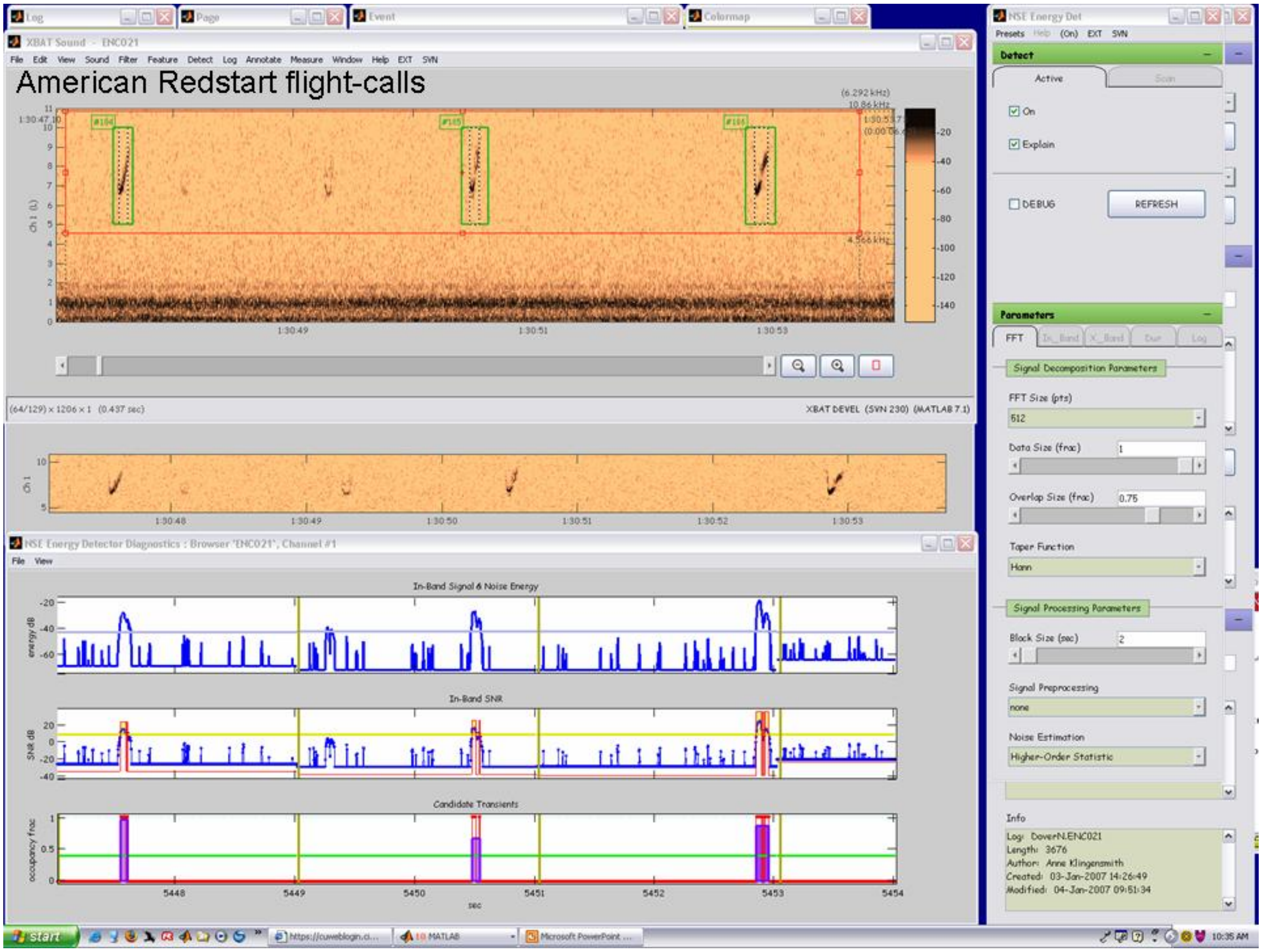

Figure 4a. Energy detection algorithm used on American Redstart flight-calls as seen on screen in XBAT version 0.7. Upper left, mp3 sound file spectrogram with American Redstart flight-calls highlighted as green selections indicating visually detected calls. Black and white hatching indicates energy detector detection. Below is a zoomed window of the three calls highlighted in the red box. Bottom left is the diagnostic tool showing frequency band of analysis (in-band), signal to noise ration (SNR), and candidate transients (flight-calls highlighted in purple). Right of the screen is the dialog box to set parameters of the energy detector.

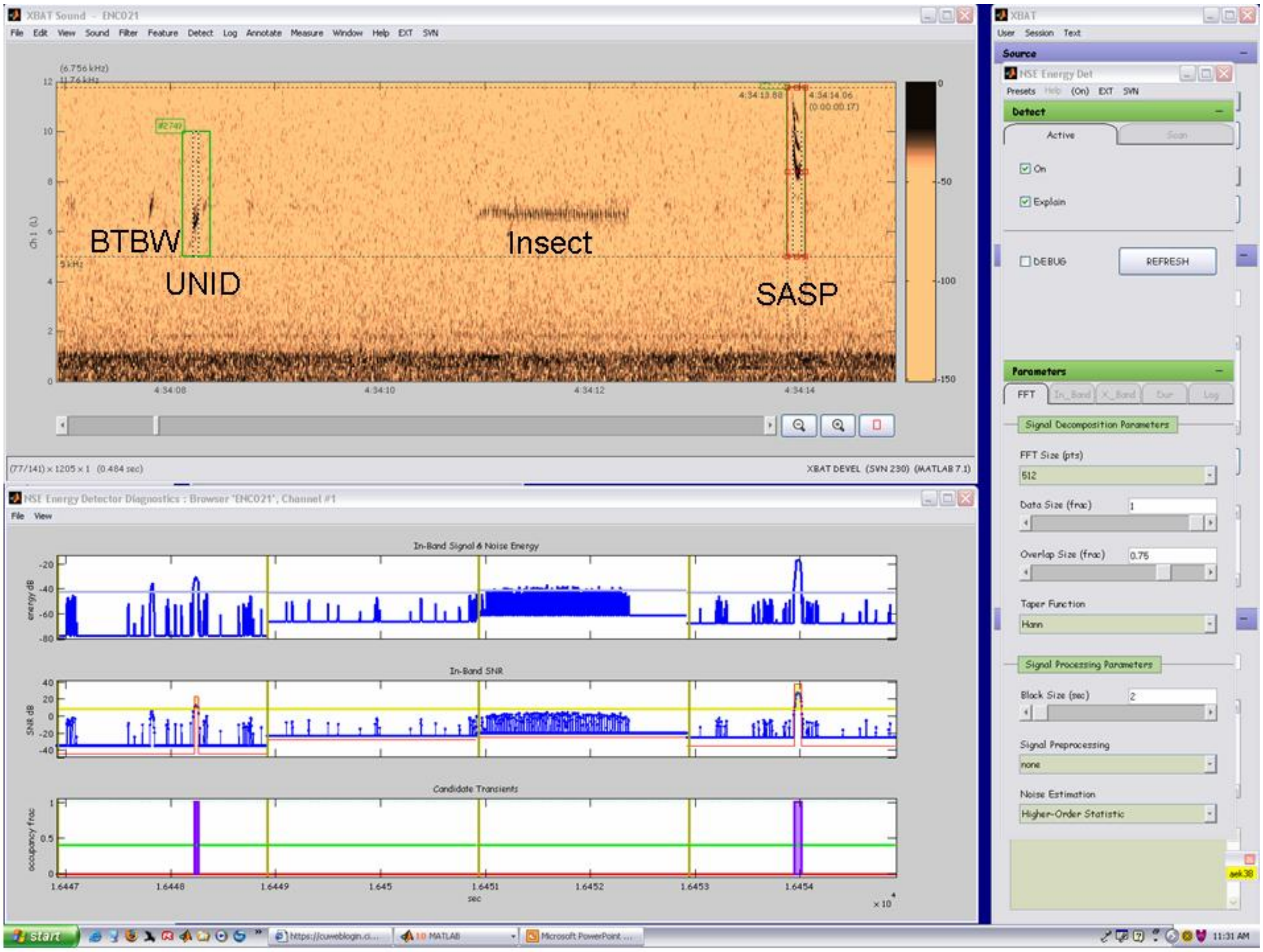

Figure 4b. Energy detection algorithm used on flight-calls and insect stridulating as seen on screen in XBAT version 0.7. Upper left, mp3 sound file spectrogram with Black-throated Blue Warbler (BTBW), unidentified flight-calls (UNID), and Savannah Sparrow (SASP) flight-calls highlighted as green selections. The additional portions of the window follow the description of Figure 4a.

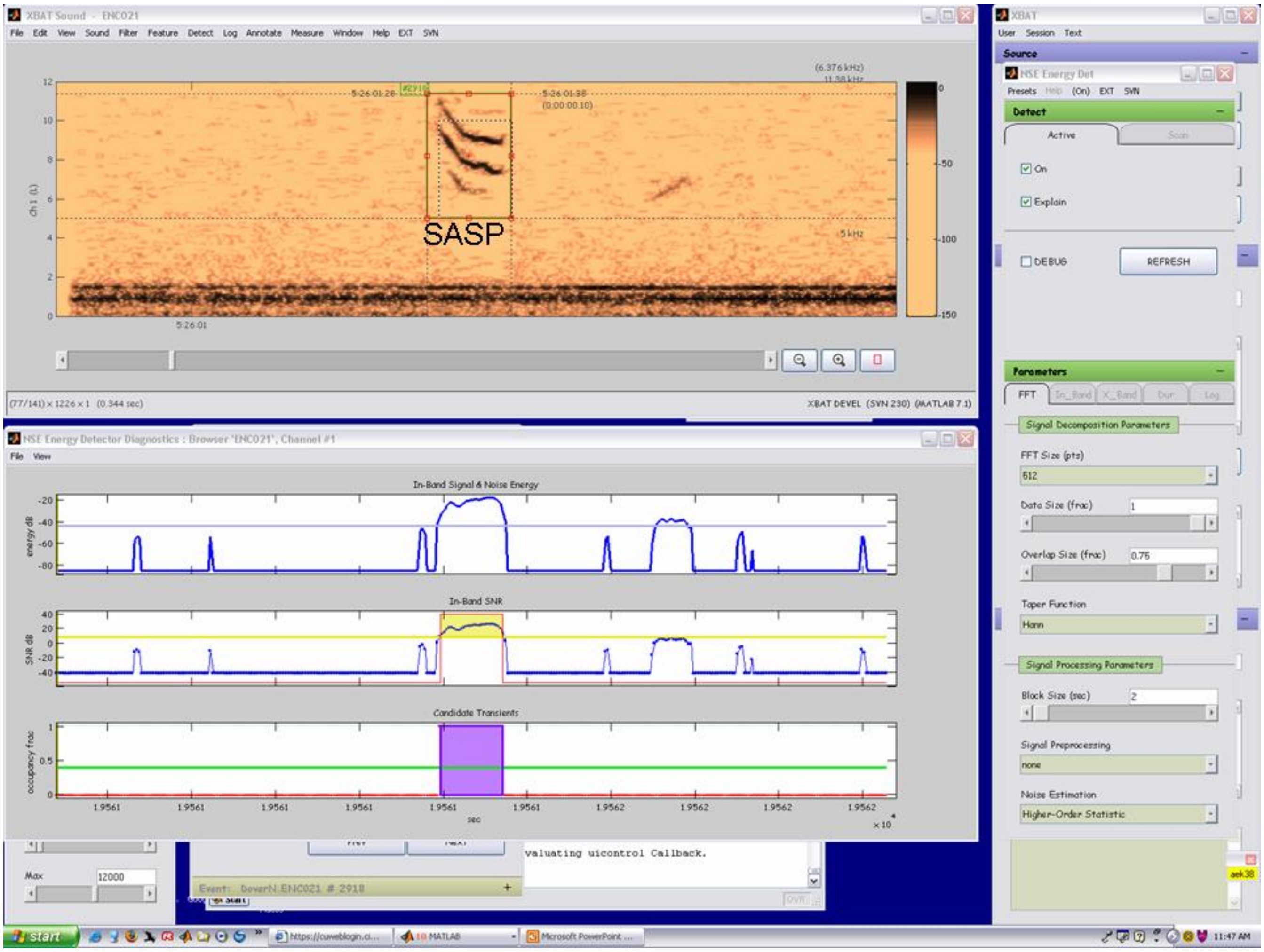

Figure 4c. Energy detection algorithm used on Savannah Sparrow (SASP) flight-calls as seen on screen in XBAT version 0.7. Details of the screen follow descriptions of Figure 4a and 4b.

We faced additional challenges in early stages of our sound analyses; we did not have diagnostic tools to streamline the use of the energy detector, thus necessitating the trial and error approach. Once we incorporated diagnostic tools into our use of the energy detection algorithms, we were able not only to understand the exact functions of the parameter settings and their affect in modifying the algorithm but also to determine easily the effects of changing each parameter, singly or in concert with other parameters, across sound recordings (Figure 5 a, b). Such diagnostic tools are vitally important for understanding the effects of different levels of background noise on the detection capabilities of the automatic algorithms.

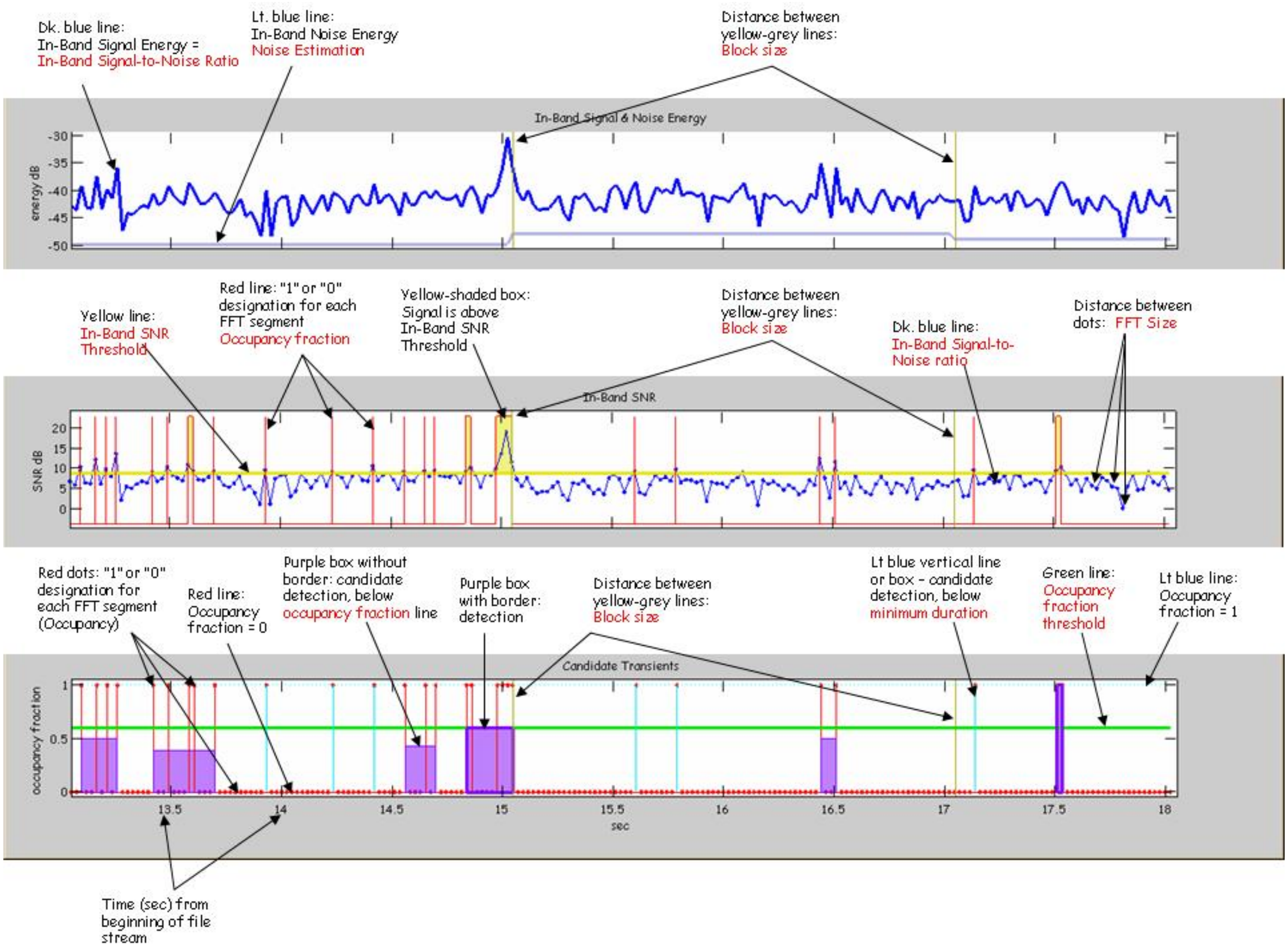

Figure 5a. Diagnostic tool definitions. Each definition represents a parameter setting in the dialog box to set energy detector algorithm settings for automated detection. Of particular importance to Legacy research are the signal to noise ratio (SNR) and duration.

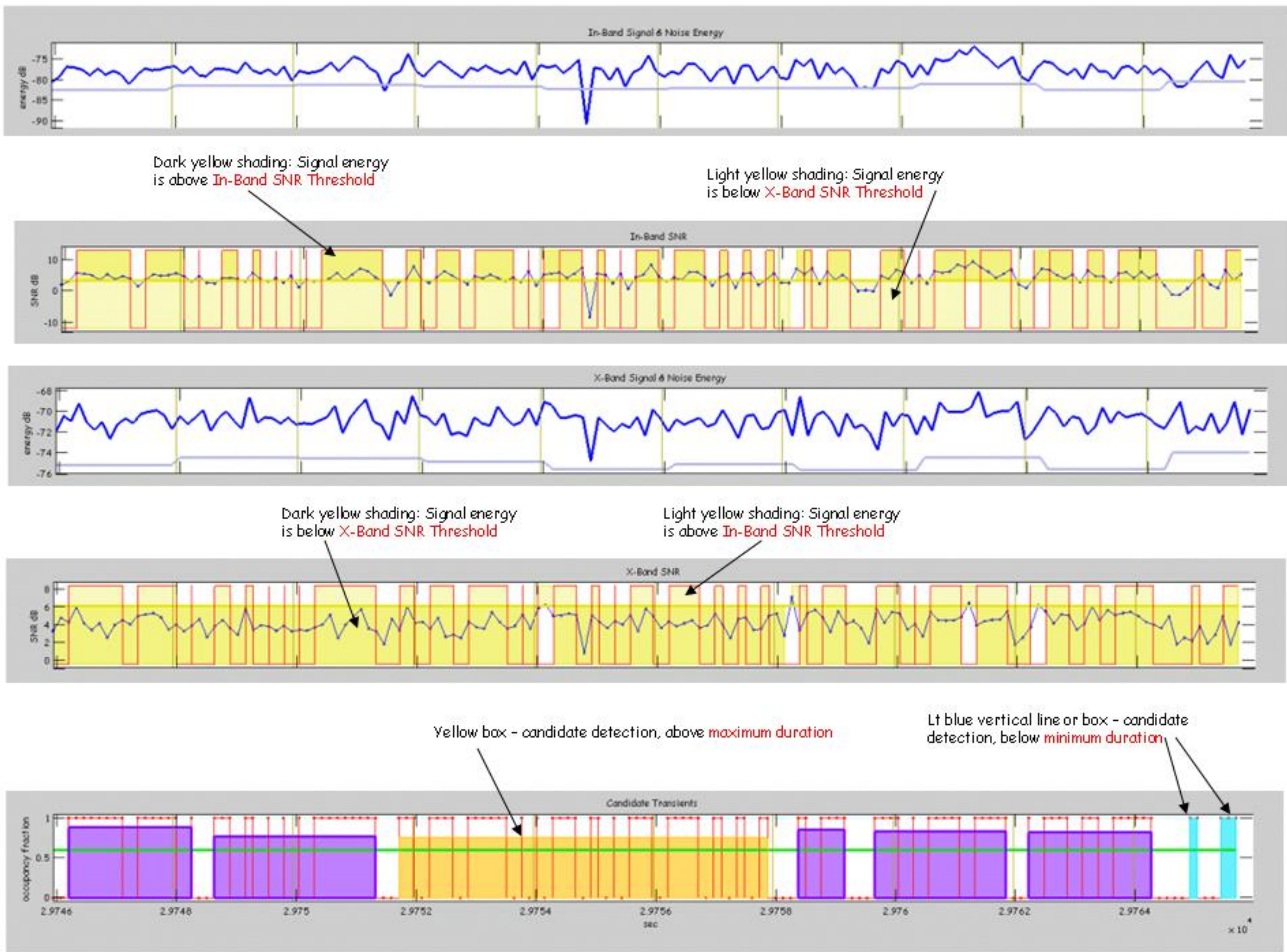

Figure 5b. Diagnostic tool definitions. Each definition represents a parameter setting in the dialog box to set energy detector algorithm settings for automated detection; however this figure contains an exclusion band setting, which allows the user to exclude signal energy in frequency bands outside of the band of interest for detecting flight-calls.

Data analysis

We have been exploring the use of automatic detection algorithms to facilitate faster analysis of sound files containing flight-calls. Often these files are large, containing tens of hours of data. Automatic detection using algorithms designed to detect specific signal energy parameters is a useful way to begin to speed this process. However, choosing the parameters is a challenging process, requiring some trial and error. We have tested such a detector extensively, and we are beginning to develop the parameters that detect 10-20 times faster than real time with a success of 40-50%. This success varies extensively from 0-10% to 90-100%. We have compared all detectors against an expert classification by visual inspection, detecting all of the flight-calls present in a sound file. This process of development and troubleshooting has been extensive, and we will continue to proceed with this development until we have a stable range of detection success.

Hardware

Hardware failure was a major problem during the first year of this program. We deployed ARUs and mp3 units, many of which failed (Table 3). Reasons for failure included compromised housing design, producing situation in which water leaked into the compartment housing the microphone and recording drives; drive failures, in which the operating system underlying the recording in the drives failed and did not record; and microphone failure in which the microphone design was not optimal. We corrected many of these problems in time to collect data; however, because many units failed we were unable to collect as much data as possible. As a result of these failures, we began to develop new housing for the microphone and recording devices as well as to choose new recording devices with higher success rates. We found that, whereas ARUs required some major developmental changes, mp3 units required much additional testing. One problem with mp3 units is that there is an unknown amount of time between writing a sound file and beginning a new sound file. This period of time is in the range of 5-15 minutes, but we do not know the exact periods over which this delay occurs. This makes automatic localization impossible, because recording in these units is not synchronized. Future use of such units for location purposes absolutely requires additional testing with external sound sources to calibrate and to synchronize time among units.

Year	2005	2006
Total MP3 units:	21	8
Total MP3 units with significantly less data than possible:	12	4
Total BIN:	-	12
Total ARUs with significantly less data than possible:	-	6

Table 3. Failure rates for mp3 and BIN units in 2005 and 2006. In both of these seasons, our project realized failure rates of approximately 50%. This is largely a result of suboptimal design of the housing for the units and problems with the operating systems of the mp3 and BIN units.

For some units, determining start times was impossible because of the manner in which the mp3 units we employed write data to sound files. The amount of time that the unit is not recording is unknown, and as such we need to recalibrate all of our recordings such that each new file begins at a slightly different time. An additional complication is that we needed to establish this time relative to civil twilight to understand what portions of a sound file contain useful nocturnal data.

Contamination

We found extensive contamination in the sound files from non-avian noises such as insects and non-biological sources such as aircraft, gunfire, and automobiles. Placement of recording units in quiet areas is certainly critical for recording bird vocalizations. However, non-biological noise is relatively easy to filter; it sounds and looks distinct from bird vocalizations, and it is possible to create some algorithms to remove the effects of this noise. Insect noise is a greater problem, particularly in that many species of grasshoppers and crickets produce sounds in the range of many flight-calls. As such, positioning microphones away from trees will minimize the effects of katydids and some other insects. Positioning the microphones away from grassy areas, if possible in paved locations or on top of buildings, will greatly minimize the effects of insect noise. Although non-biological noise is relatively easy to filter by eye, by ear, and by machine, it still poses a problem. During periods in which aircraft pass over the microphone, no flight-

calls can be recorded. The amount of noise from these sounds relative to the volume of flight-calls differs by orders of magnitude. This problem also occurs for other sounds such as gunfire and exploding ordnance. However, all of these are sporadic sources of noise, not continuous, and therefore simply pose problems when they occur. Wind and road noise, particularly noise from Interstates or heavily traveled roads, could pose more of a problem. However, most of this noise, though continuous, is low frequency noise below the range of most flight-calls. The most likely species with which such noise would interfere, however, are larger migrant herons and waterfowl, species that could pose significant threats for bird strike hazard. With this in mind, positioning units to minimize continuous low frequency noise and sporadic high energy noise is a must.

Data storage, file-naming, and file compression

Each recording unit can record up to 4-6 weeks of data, depending on available battery power and recording attributes such as sampling rate and sample size (converting incoming sound to digital data). Given this quantity of information, data management is critical. Storage for these data quickly becomes an issue in terms of how to access this information easily and where to keep it such that it is organized. We needed to acquire substantial space for storing these files such that they could be easily accessed (a server) as well for creating copies to duplicate data to avoid loss of original data. Additionally, naming the files such that they can be easily located and identified requires explicit attention. Each unit writes files with different naming conventions, some times with conventions that do not allow for explicit identification of recording date, location, and timing; therefore, creating informative but relevant names for these files is important.

Sound files recorded by ARUs are compressed (mp3 files rather than aif or wav files) and require smaller amounts of storage space than do non-compressed data (Table 4). Compressed data may represent a viable solution to storage space issues, although access to larger and less expensive drives may make this problem obsolete. Mp3 files are convenient because compression reduces their file size and as a result expands the recording capacity of a hard drive or storage environment by several times. However, compression poses a potential problem for these data - higher frequencies are more prone to compression related artifacts than lower frequencies (such as creating spurious frequencies that are not actually present), and many species of birds have flight-calls in this problematic zone. Although species identification is still possible with these data, no information exists as of yet regarding the extent of potential problems for classification using mp3 or other types of files. Binary files are uncompressed, and as a result take up larger quantities of space that do the same length mp3 files. However, these uncompressed data represent a more accurate representation of the actual sounds recorded, their accuracy compromised only by the choice of sampling size and rate rather than compression attributes and sampling specifications.

Conversion:	Size (GB)	Recording Length (HH:MM:SS)
MP3	1.0	18:38:29
BIN	1.0	7:28:36
BIN	1.07	8:00:00

Table 4. Conversion factors for mp3 and BIN files. Note that the same size mp3 and BIN files represent drastically different total recording lengths.

Arrays

We encountered challenges while trying to localize birds in time and space. Array recordings to localize birds in space require absolute time synchronization to determine when sounds reach given portions of an array. Such delays are critically important for determining the origin point of the sound. However, additional problems relating to the resolving power of altitudinal arrays pose concerns as well. Determining the proper distance to position microphones relative to the frequency of the bird vocalizations and relative to the expected heights of migration is critical for implementing the array technology. We feel that much further research is necessary before such a system could precisely and accurately locate birds by their flight-calls. However, we are continuing to investigate new ways of doing exactly this, and in second and third year funding we will be devoting a portion of our recording season to developing these ideas on paper with the goal of trying to test them in the field in the final year of the project.

Additional monitoring efforts and partnerships

The three components of this proposal are part of a long-term effort to enhance bird-monitoring capabilities through innovative acoustic and internet technologies. We are expanding the field testing and deployment of autonomous recording units from the first year to include additional DoD and non-DoD installations in future years, with the plan to provide eventually the capacity to serve all DoD lands as well as adjacent regions. As such, the local networks of FC monitoring stations on and around DoD bases would form the start of what will eventually be a continent-wide network that would provide measures of species migration traffic on regional and continental scales. Additionally, we will be expanding our acoustic monitoring in spring 2007 to develop and to test protocols to monitor species that vocalize infrequently by deploying ARUs over periods of weeks or months to document changes in vocalization rates in relation to environmental factors at breeding sites where the local density is known. In particular, we are planning to deploy units to monitor rare species (Black Rail) and species that vocalize infrequently (Whip-poor-will).

The innovative monitoring network we proposed and the data we have begun to collect provides the tools and the information to monitor migratory activity by species, contribute towards more accurate population estimates for these species, and provide information for more accurate environmental risk assessments (Migratory Bird Treaty Act and Endangered Species Act) and Integrated Natural Resource Management Plans. The proposed migratory bird network documents migratory phenomena that are unobservable by other means, and enable studies that extend beyond the boundaries of DoD installations, addressing three challenges confronting DoD: acquiring more detailed information to reduce bird strike hazards, meeting environmental stewardship obligations while managing the ongoing financial and operational costs, and engaging broader societal support and solutions for environmental problems.

We are facilitating increased partnerships through our monitoring efforts from the first year of this project. An important collaborative adjunct to this work is the extensive nocturnal flight-call monitoring project headed by Deanna Dawson (USGS) and Tim Jones (FWS) as part of the Atlantic Coast. Beginning in spring 2007, we hope to collaborate explicitly with this group to expand our network of flight-call monitoring stations, facilitating collection of larger training datasets and improved and increased comparative analysis of migration across a broader geographic context.

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